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BRL

REPORT NO. 165

STABILITY OF 90MM SHELL T3

by

H. P. Hitchcock

November 1939

U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

Ballistic Research
Laboratory Report No. 165

HPH/dem
Aberdeen Proving Ground, Md.,
November 1, 1939.

STABILITY OF 90 MM SHELL T3.

Project KR 563.

ABSTRACT

It is found that the stability factor of the 90 mm A.A. Shell T3, with the Mechanical Time Fuze M43, fired from the A.A. Gun T2 with a twist of rifling of 1/30 at a muzzle velocity of 2800 f/s, is 1.515. If the twist were reduced to 1/32, the stability factor would be 1.33, and the projectile would still be sufficiently stable. A twist of 1/30 is recommended.

CONTENTS

Par.

Table

Firing record No. 13032.

1. AUTHORITY: These firings were authorized by the third paragraph of letter O.O. 471.91/2899 (APG 471.9/13c).

2. OBJECT: On the basis of stability firings of the T3 Shell in the T1 Gun, with a twist of rifling of one turn in 20 calibers, at a muzzle velocity of 1920 f/s, it was recommended in Report No.150 that the antiaircraft proof gun be given a twist of rifling of 1 turn in 30 calibers. The present firings were conducted with the proof gun to check the prediction and to determine the proper twist for the pilot gun.

3. GUN: 90 mm A.A. Gun T2, which was rifled with a twist of 1 turn in 30 calibers.

4. SHELL: 90 mm H.E. Shell, A.A. T3 (Dgr. 75-18-39).

5. FUZE: Inert, Point Detonating Fuze M48.

6. POWDER: Lot D.P. X 740-1918 for 4.7" Gun, 6 lb. 14 oz. to give an estimated muzzle velocity of 2800 f/s.

7. YAW SCREENS: Since the gun was on a fixed mount, it had to be fired at the antiaircraft range. Frames were attached to wooden poles at the following distances from the muzzle: 60, 80, 100, 120, 140, 160, 180, 200, 220, 300, 400, 500, 560, 580, 600, 620, 640 feet. The yaw screens consisted of 80-chip cardboards, 4 feet square. For thick distribution, they were placed on all frames. For thin distribution, there were three near the first maximum yaw, three near the first minimum yaw, and five at the end of the range.

8. FIRINGS: Only five shell were available in August. Three of them were fired through thick distribution on the 29th, and two through thin distribution on the 31st. A recommendation that the rifling of the pilot gun be given a twist of 1/30 was based on the approximate observed period of the first three rounds, with an estimated correction. On October 3d and 4th, five more rounds were fired: two through thick, and three through thin distribution. Shell No. 1 (fired August 29th) hit the side of the frame at 500 feet. The last minimum yaw of shell No. 9 could not be located exactly. The other eight rounds gave reliable results.

9. DYNAMIC DATA: The front and rear bourrelets of the shell were machined to a diameter of about 3.525 inches. The center of gravity and moments of inertia were then determined in the manner explained in Report No. 150. The axial moment of inertia of a mechanical time fuze M43 was found to be 0.0049 lb.ft^2, which is practically the same as that of the M48 Fuze. Shell No. 5 was also weighed, balanced, and swung transversally with an M43 Fuze instead of the M48 Fuze: this decreased the weight by 3/4 oz., moved the center of gravity 0.012 in. forward, and increased the transverse moment of inertia 0.027 lb.ft^2. The dynamic data are tabulated in Table I.

10. STABILITY:

a. The maximum and minimum yaws, the period of nutation, and the rate of precession are given in Table II. The observed rate of precession is close to the theoretical rate, which is determined from the moments of inertia and the twist of rifling.

b. The results are given in Table III. The cardboard constant was determined by the method of least squares: the points representing the reduced period as a function of the correction factor lie exceptionally close to the mean line. The form factor used in correcting the stability factor for loss of velocity is 1.05 with respect to G_2, as before.

c. The average stability factor of the 90 mm A.A. Shell T3, with P.D. Fuze M48, fired from the A.A. Gun with a twist of rifling of 1/30 at a muzzle velocity of 2800 f/s, is 1.52. The corresponding moment coefficient is 1.11 (= 4.83×10^{-5} lb/in^3). Since this projectile has a 1/2 caliber 7° boat-tail, a 1.72 cal. body, and a 2.36 cal. ogive, it is estimated on the basis of 3.3" results that the center of pressure h is 2.7 cal. from the base. The average measured center of gravity g is 1.785 cal. from the base. Hence, the normal force coefficient is 1.21.

d. Although the Mechanical Time Fuze M43 is slightly lighter than the P.D. Fuze M48, its center of gravity is farther forward. The average center of gravity of the shell, corrected for this difference, is 1.789 cal. Since both fuzes have standard contour, the center of pressure and normal force coefficient would be the same. Hence, the moment coefficient of the T3 Shell with the M43 Fuze is 1.10. The axial moment of inertia is practically the same with both fuzes, but the transverse moment of inertia is different: 2.472 lb.ft^2 with the M48 Fuze and 2.499 lb.ft^2 with the M43 Fuze. Since the stability factor is inversely proportional to the transverse moment of inertia and the moment coefficient, it is 1.515 for the 90 mm A.A. Shell T3 with the Mechnical Time Fuze M43, fired from the A.A. Gun with a twist of rifling of 1/30 at a muzzle velocity of 2800 f/s.

11. RECOMMENDATION: In accordance with the recommendation made in Report No. 150, based on firings in the T1 Gun at a muzzle velocity of 1920 f/s, the Proof Gun T2 was rifled 1/30. A rough calculation based on the first three rounds fired in the latter gun indicated that this twist was correct: consequently, a recommendation was made by teletype on August 29th, and confirmed by letter dated August 30th , that the pilot gun be rifled 1/30 also. Although this will be satisfactory from the standpoint of stability, the above results indicate that the T3 Shell with M43 Fuze is more stable at 2800 f/s than it was estimated to be. If the twist were 1/32, as originally prescribed by O.C.M. item 14589, the stability factor would be 1.33. Therefore, if it is considered urgent to reduce the spin for the sake of

improving the functioning of the fuze, future guns of this type may be rifled with a twist of 1 turn in 32 calibers. Otherwise, it is recommended that the present twist be retained.

H. P. Hitchcock

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TABLE I

DYNAMIC DATA

Shell No.	Fuze	Weight (lb.)	C.G. to base. (in.)	Moments of Inertia. (lb.ft^2)	
			g	A	B
1	M48	20.703	1.776	.2522	2.454
2	"	20.516	1.778	.2514	2.483
4	"	20.562	1.777	.2514	2.480
3	"	20.641	1.778	.2528	2.481
5	"	20.766	1.777	.2546	2.479
6	"	20.609	1.795	.2522	2.469
7	"	20.672	1.795	.2530	2.469
8	"	20.703	1.793	.2535	2.476
9	"	20.734	1.787	.2539	2.494
10	"	20.625	1.795	.2532	2.431
Ave.	M48	20.653	1.785	.2528	2.472
5	M43	20.719	1.781	.2546	2.506
Ave.	M43	20.606	1.789	.2528	2.499

TABLE II

STABILITY DATA

Shell No.	Yaw (deg.) First Max. α_1	Yaw (deg.) Last Max. α_n	Yaw (deg.) First Min. β_1	Yaw (deg.) Last Min. β_n	Muzzle to Min. Yaw (ft) First m_o	Muzzle to Min. Yaw (ft) Last m_n	Number of Periods n	Average Period (ft) L_a	Precession (semi-rev./ft) Theo. A/dnB	Precession (semi-rev./ft) Obs. φ'_π
1	---	---	---	---	---	---	---	---	.0116	---
2	5.6	5.5	0	0	190	635	3	148.3	.0114	.0114
4	4.1	4.1	0	0	185	625	3	146.7	.0114	.0121
3	5.1	4.2	0	0	170	605	3	145.0	.0115	.0124
5	6.0	3.9	0	0	165	585	3	140.0	.0116	.0116
6	6.4	3.9	0	0	175	650	3	158.3	.0115	.0115
7	6.7	4.0	0	0	170	650	3	160.0	.0116	.0121
8	5.8	3.7	0	0	170	610	3	146.7	.0116	.0118
9	4.4	2.2	0	0	165	---	---	---	.0115	---
10	3.9	2.8	0	0	170	595	3	141.7	.0118	.0123

TABLE III

STABILITY RESULTS

Shell No.	Air Density (ratio) ρ	Correction Factor $\frac{\Sigma(\delta/\alpha)^2}{n}$	Card-Board Const. c	Period Without Cards L_c	Stability Factor Without Cards s_c	Stability Factor At Muzzle s_o	Stability Factor At $\rho = 1$ s_ρ	Moment Coef. K_M	Card-board Dist.
1	1.002	---	---	---	---	---	---	---	Thick
2	1.002	1.618	6.34	138.0	1.678	1.632	1.635	1.01	"
4	1.003	1.502	"	137.2	1.569	1.528	1.533	1.08	"
3	.993	0.185	"	143.8	1.459	1.422	1.412	1.19	Thin
5	.990	0.106	"	139.3	1.616	1.576	1.560	1.09	"
6	1.040	1.575	"	148.3	1.520	1.479	1.538	1.09	Thick
7	1.043	1.648	"	149.6	1.436	1.397	1.457	1.16	"
8	1.033	0.496	"	143.6	1.529	1.490	1.539	1.10	Thin
9	1.033	---	"	---	---	---	---	---	"
10	1.032	0.384	"	139.3	1.512	1.474	1.521	1.19	"
Mean (rounds with thick distribution 1/2 weight)							1.519	1.11	

ABERDEEN PROVING GROUND FIRINGS

Object of Firing: Stability of T3 Shell

Aug.29,31,1939 and
Date of Firing Oct.3,4,1939
Firing Record No. 13032
Sheet 1 of 4
T. S. T. P.
O. C. M. Item
O. P. No. KR563
Contract No.
O. O. File 471.91/2769
A. P. G. File 471.9/13A
W. O. No. 326-2

DEVELOPMENT

Related F. R. Nos.

ck

	CALIBER	MODEL	MANUFACTURER	No.	ROUNDS FIRED PRIOR TO TEST
Cannon	90 M/M A.A.Gun	T2	Watervliet Ars.	1	24
Carriage	105 M/M A.A.Gun	M1	Watertown Ars.	1	
Recoil Mech.					

Azimuth of line of fire 42°15' Deflection from AP Mils

Gun position Antiaircraft Range Target

Projectile	90 M/M T3, Lot E1787-156
Bursting charge	
Booster	M20, Inert, P.A. Lot 1142-1
Fuze	Point Detonating, Inert, M48, P.A. Lot
Powder	DuPont Co's. Smokeless Powder Lot X-740-1918 for 4.7" Gun, M1906
Case ~~ordnance~~	90 M/M, T3, F.A. Lot 2238-1
Igniter	
Primer	M28, P.A. Lot 571-1

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ABERDEEN PROVING GROUND FIRINGS

F. R. No. 13032
Sheets 2 of 4

GENERAL DATA BY ROUNDS

1939 DATE	ROUND No.	TIME OF FIRING	PROJECTILE No.	PROJECTILE Weight as Fired Lbs.	PROJECTILE Ozs.	POWDER Lot	POWDER Box No.	POWDER Charge Weight Lbs.	POWDER Charge Weight Ozs.	ELEVATION Depress.	PRESSURE Meas.	VELOCITY Est.	Shell No.
Aug. 29	25	2:35		20	11-1/4	X-740		6	14	1 16	33200	2800	1
	26	3:00		20	8-1/4	"		"	"	" "	33800	2800	2
31	28	9:30		20	10-1/4	"		"	"	1 13	34500	"	3
29	27	3:15		20	9	"		"	"	" "	33500	"	4
31	29	10:15		20	12-1/4	"		"	"	" "	33800	"	5
Oct. 3	30	4:12		20	9-3/4	"		"	"	Depression 1 16	34700	"	6
4	31	9:53		20	10-3/4	"		"	"	" "	33100	"	7
	32	10:45		20	11-1/4	"		"	"	" "	34800	"	8
	33	11:22		20	11-3/4	"		"	"	" "	34900	"	9
	34	11:51		20	11	"		"	"	" "	35000	"	10

Distance wads used on all rounds.

ABERDEEN PROVING GROUND FIRINGS

F. R. No. 13032
Sheet 3 of 4
Date Aug. 29, 31, 1939
Oct. 3, 4, 1939

PRESSURE DATA

Type of gauge Medium Caliber
Position of gauge Base of Cartridge Case
Metal of crusher cylinder May 26, 1919. Annealed June 2, 1919
Initial compression 0

ROUND NO.	BAND DIAM. INS.	GAUGE NO.	PRESSURE 100	GAUGE NO.	PRESSURE 100	GAUGE NO.	PRESSURE 100	GAUGE NO.	PRESSURE 100	MEAN
25		458	342	490	322					332
26		280	334	464	342					338
28		419	342	62	348					345
27		413	334	492	336					335
29		378	356	61	320					338
30		362	350	358	344					347
31		464	346	432	316					331
32		370	344	437	352					348
33		319	356	449	342					349
34		408	356	59	344					350

Pressures in this report are calculated and read to the nearest one hundred lbs.

ABERDEEN PROVING GROUND FIRINGS

F. R. No. 13032
Sheet 4 of 4
Date Aug. 29, 30, 1
Oct. 3, 4, 193

MISCELLANEOUS DATA

WIND DATA

Round No.	Direction	M.P.H.	Atmospheric Temperature
25	E	16	64° F.
26	ENE	17	64° F.
28	NNE	13	72° F.
27	ENE	18	64.5° F.
29	NNE	13	71.5° F.
30	N	12	53.5° F.
31	NNW	5	52° F.
32	NNW	6	56° F.
33	NNW	5	56° F.
34	N	5	56.5° F.

Rounds 25 to 27 and 30 and 31 - Fired through thick distribution of cardboard screens.

Rounds 28, 29, 30 and 32 to 34 - Fired through thin distribution of cardboard screens.

Cardboard Screens - 40-chip, used on all rounds. Each card was leveled before firing.

No change in gun or carriage since last firing.

Gun and carriage functioned satisfactorily.

There were no misfires, hangfires, flarebacks or evidence of unconsumed powder on any round.

Present for test: Mr. H. Hitchcock, Ballistic Division, A.P.G.

APPROVED:

J. B. ROSE,
Colonel, Ord. Dept.,
Commanding

BY: Burton G. Lewis

BURTON G. LEWIS,
Col. Ord. Dept.,
Officer in Charge
of Proof Dept.

George S. Groak

GEORGE S. GROAK,
Prin. Lab. Mechanic,
Proof Officer

GPO 104454

DEPARTMENT OF THE ARMY
UNITED STATES ARMY RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND 21005-5066

REPLY TO
THE ATTENTION OF

AMSRL-CS-IO-SC (380) 28 JAN 2000

MEMORANDUM FOR Defense Technical Information Center,
ATTN: DTIC-BCS, 8725 John J. Kingman Road
Suite 0944, Ft. Belvoir, VA 22060-6218

SUBJECT: Distribution Statement for BRL Report No. 165

1. Reference: Ballistic Research Laboratories Report No. 165, "Stability of 90MM Shell T3, Project KR 563", by H. P. Hitchcock, November 1, 1939, AD 491819.

2. The Army Research Laboratory, successor organization to the Ballistic Research Laboratories, has determined that the referenced report may be released to the public. Request that you mark your copy of the document:

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3. Our action officer is Mr. Douglas J. Kingsley, DSN 298-6960.

Constance L. Berry
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Acting Chief, Security/CI Office

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